JOURNAL OF THE
BOSTON SOCIETY
OF
CIVIL ENGINEERS

MARCH, 1928

Featuring

Concrete and Other Building Materials in Exposed Locations—With Discussion

Vol. XV No. 3

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JOURNAL OF THE

BOSTON SOCIETY OF CIVIL ENGINEERS

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Published Monthly, except July and August, by the Society
715 Tremont Temple, Boston, Massachusetts

Subscription Price, $4.00 a Year (10 Copies)
50 Cents a Copy

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Entered as second-class matter, January 15, 1914, at the Post Office at Boston, Mass., under Act of August 24, 1912.

Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized on July 16, 1918.

The Society is not responsible for any statement made or opinion expressed in its publications.

BOSTON
WRIGHT & POTTER PRINTING COMPANY
32 DERNE STREET

JOURNAL OF THE
BOSTON SOCIETY OF CIVIL ENGINEERS

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CONCRETE AND OTHER BUILDING MATERIALS IN EXPOSED LOCATIONS

By John J. Harty,* Member, Boston Society of Civil Engineers

For the purposes of discussion building materials may be divided into four principal groups, namely, the metallic group, the natural stone group, the clay products group, and the concrete and cement products group.

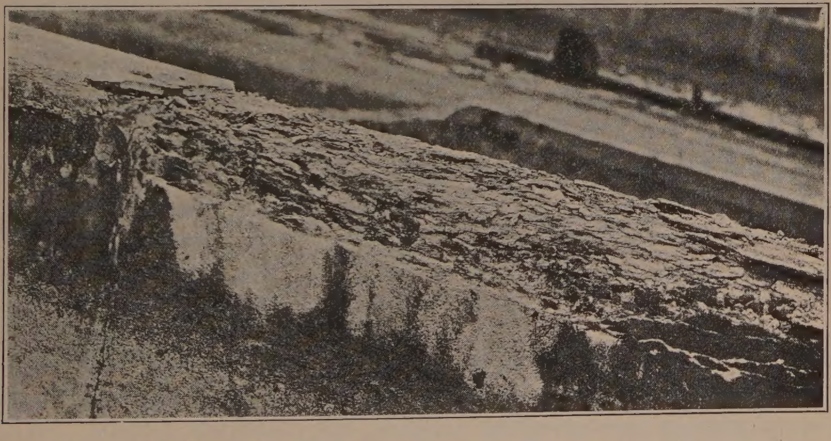

Fig. 1. — A Portion of Wall of Cooling Pond at the Maverick Mills, East Boston

We will pass lightly over the first three, as it is believed most of the interest at this time centers about the last.

Considering the metallic group, we need only mention that those materials subject to deterioration upon exposure are generally afforded protection in the form of masonry or paint, the latter requiring frequent renewals.

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* Consulting Engineer, 25 Huntington Avenue, Boston.

The natural stone group has given a pretty good account of itself in its resistance to destruction by the elements. Materials of this group, in common use, are granite, limestone, marble and slate, with occasionally sandstone. Granite is, of course, permanent. Limestone, probably the most commonly used of all natural stones, is quite durable. While it lacks a great deal of strength, especially in bending, its pleasing appearance, durability and the ease with which it may be carved have been the principal factors towards its popularity. Marble, the next to be considered, is a sort of first cousin to limestone. Different varieties vary greatly in their ability to withstand the elements. Some of the softer ones, and more particularly some of those composed of hard pieces embedded in a soft matrix, notably Brescia, disintegrate in a very short time. Slate, of the kinds in common use, is generally considered satisfactory. The external use of slate is confined almost exclusively to roofing, — a more exposed location than is common for the other stones. Sandstones of the harder varieties, especially those in which silica is the cementing material, are extremely durable. With sandstone it is very important that the bed faces be not exposed. Years of experience have familiarized architects and engineers with the lasting qualities of the different stones, and most of the unsatisfactory ones have been relegated to the discard.

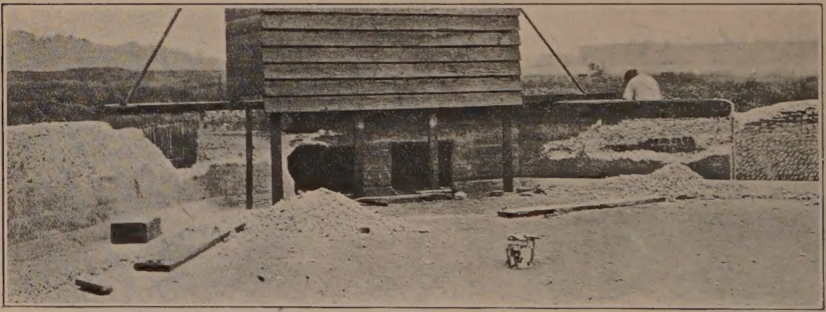

FIG. 2. — ANOTHER PORTION OF WALL OF COOLING POND AT THE MAVERICK MILLS, EAST BOSTON

We will now consider the clay products group. This group comprises brick, plain and ornamental terra cotta, roofing, flooring tile, etc. The only material of particular interest to us in this discussion is ornamental or architectural terra cotta, the others, when of good quality, being generally satisfactory. Architectural terra cotta was used quite extensively in some of the older buildings in Boston. Of late years its popularity seems to have been on the wane, the only very recent example of its use that comes to mind being the new Statler Hotel. This material seems very unreliable, and there is little question that this unreliability is responsible for its decreasing popularity. Some buildings of this material have stood for years without appreciable signs of depreciation, while others, apparently satisfactory when erected, have developed crazing, which, followed by the combined action of moisture and freezing temperatures, has caused the surfaces to disintegrate and spall off. Another fault to be found with this material is that in order to avoid excessive warping of the blocks it is necessary to restrict their size to such an extent as to be "out of scale with the building."

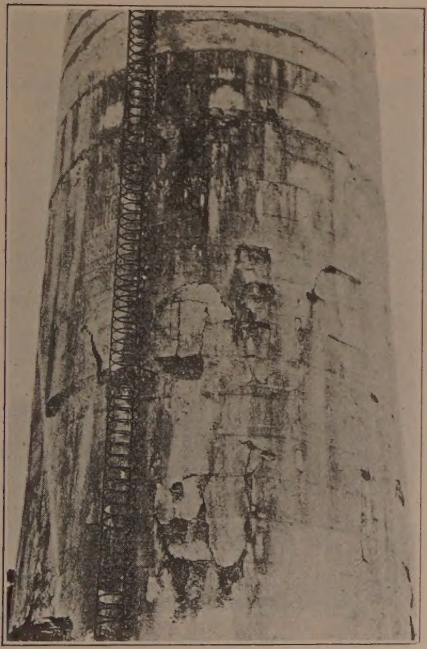

Fig. 3. — Disintegration of Reinforced Concrete Standpipe at Lexington, Mass.

Now comes the concrete and cement products group. Concerning concrete much has been said both for and against its use, both structurally and as a protective covering for structures. We are not to concern ourselves here with the pros and cons of the case of "Concrete *v.* Structural Steel," but we are here primarily to discuss the faulty weather resistance of concrete. Concrete in an exposed location without fault is decidedly rare. This is not intended as a blanket condemnation of the material, for a large majority of concrete structures, while showing signs of having been affected by the elements, are still standing and carrying their loads. Few are the cases, comparatively speaking, where the concrete has disintegrated to such an extent as to be dangerous or beyond repair. However, the popular theory of a few years ago, that concrete was like good whiskey, improving with age, has been somewhat shaken. The faults in concrete vary from minute crazing to complete disintegration, and if they do not take this form, there are unsightly board marks, irregular exposure of aggregate, cracks due to shrinkage, holes due to segregation of aggregates or accumulation of laitance, winds and bulges caused by movement of forms, and spalling caused by rusting of reinforcement.

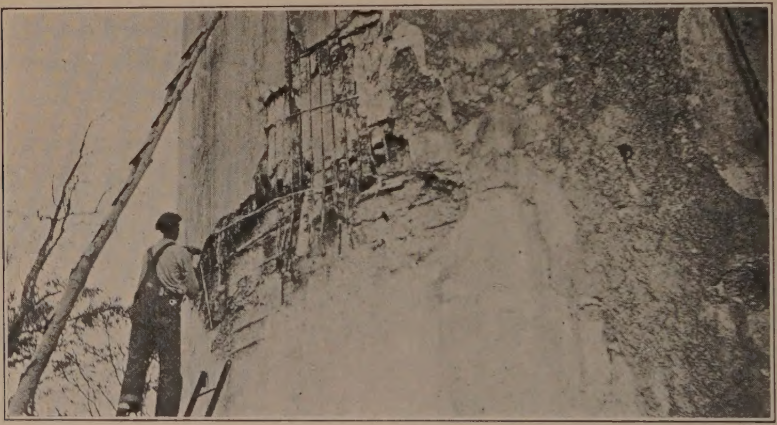

FIG. 4. — BADLY DETERIORATED PORTION OF REINFORCED CONCRETE STANDPIPE AT LEXINGTON, MASS.

Many of these faults have nothing to do with weather resistance, and, also, many may be minimized by proper design and construction, but present knowledge is apparently incapable of coping with all the difficulties. Take the matter of crazing, — the most prevalent of faults and the forerunner of most disintegration, though not always followed by it. Many are the opinions regarding its causes. One will say the sand was too fine; another will point to satisfactory structures in which only fine sand was used; another will say the concrete was too wet; another that the fines were spaded to the surface, causing laitance to gather; another that the surface was worked excessively after the removal of the forms; another will blame it on the use of cement in the rubbing-down; another will say that the surface was allowed to dry too quickly; and so on, endlessly. Without wishing to discredit any of these theories and admitting freely that any, or all of them, may have some basis, we are obliged to admit that little is known, positively, about the subject.

Crazing seems to be the first warning of disintegration. The usually accepted theory is that moisture entering these tiny cracks expands in freezing, enlarging and deepening them at each cycle of thawing and freezing until, finally, portions of the concrete fall away and the real disintegration is in progress. This theory is not adequate to explain all cases of deterioration preceded by crazing, as there are many such cases in temperate climates where frost is not a factor. Extensive investigations are being conducted at present on this subject of crazing, and important papers are to be presented at the February convention of the American Concrete Institute by Mr. P. H. Bates of the United States Bureau of Standards and Prof. Alfred H. White of the University of Michigan.

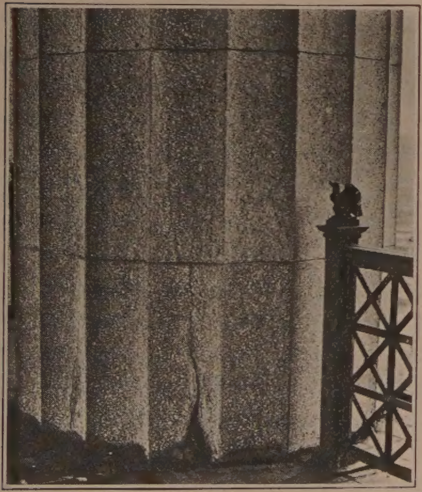

FIG. 5. — BASE OF CAST STONE COLUMN OF THE NEW GRANT PARK STADIUM, CHICAGO, ILL.

Some engineers claim that they are able to overcome the crazing tendency by removing the outer layer of concrete by tooling or otherwise, and they point to a number of structures so treated that are still in good condition after years of exposure. The fact that there are a number of smooth-finished concrete structures in which crazing is the only apparent fault gives rise to the speculation whether tooling has actually removed the crazing or merely made it less apparent.

Another prime cause for the disintegration of concrete is the corrosion and consequent expansion of reinforcement, forcing the concrete protection to spall away. Some years ago it was considered good practice to place the temperature reinforcement as close to the exposed face as possible, most engineers going on the assumption that steel embedded in concrete would not rust, no matter how thin the covering. Even now, with lack of proper care or supervision reinforcement will often be found very near the surface. One never has to search for this fault; it makes itself perfectly evident in a very short time.

Cast stone is only glorified concrete. Greater care may be exercised in the selection and control of ingredients, in the preparation of forms, in casting, resurfacing and curing, but the resulting material is concrete and subject to the same failings. One of the principal arguments advanced for the use of cast stone is economy, and when the necessary precautions are taken to assure a good product the cost of production mounts, tending to decrease or eliminate the anticipated saving. Cheap cast stone is an abomination, both æsthetically and practically. It is only necessary to glance at large numbers of speculative buildings built in the last ten years to realize what a poor product may be put on the market as cast stone.

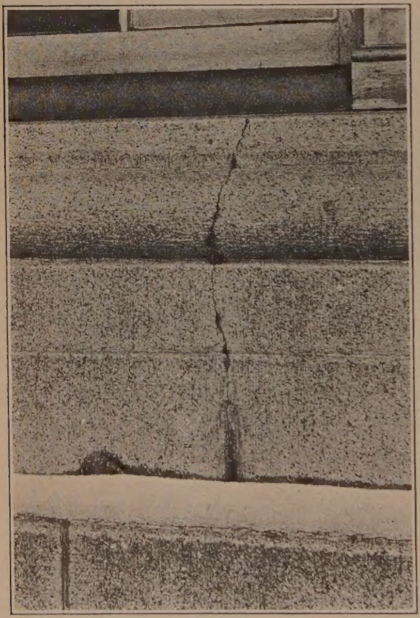

Fig. 6. — Portion of Base Course of the New Memorial Building at Lowell, Mass.

Next in this group is stucco. No one connected with the building industry has ever found a plasterer who did not know "all about stucco," and there are few materials showing such glaring failures. Perhaps some of us know how to use stucco and make it stick, but the knowledge is not common in the trade.

While concrete is one of our oldest materials, it is only within comparatively recent years that we have attempted anything like a scientific investigation of it, and certainly it is not beyond the realm of probability that we shall be able to overcome these faults which at present seem inherent in the material. Aside from poor materials and workmanship most of our troubles are undoubtedly caused by the infiltration of water, and this same infiltration is very often a contributory cause to failures of poorly made concrete. Perhaps the answer lies in providing protection in the form of waterproofing. Disintegration has often been successfully counteracted by this simple expedient, and some engineers have already adopted the practice of applying waterproofing as soon as a structure is completed.

It has been the intention, in the foregoing, simply to point out some of the outstanding faults, particularly in concrete and cement products, with a view to starting the discussion, which, it is to be hoped, will be beneficial to all of us.

Discussion

ARTHUR L. SHAW: * Concrete used in connection with plants for the treatment of sewage or industrial wastes, and the like, commonly shows signs of distress upon its surfaces in a much shorter time than does an equivalent concrete used in the ordinary building wall. Frost is one of the most potent single causes of disintegration, although the chemical reactions of certain sewages and industrial wastes may also be a factor. In a building or similar structure the destructive effect of frost is severely felt only on those infrequent occasions in winter when a sharp drop to freezing temperatures follows a rainy period which has left the concrete wet. The effect of a succession of frosty nights during fair weather has relatively little effect upon such concrete.

On the other hand, in certain of the exposed walls of a sewage treatment plant, for example, there is ever present the wet condition which makes concrete vulnerable to frost. Every cold night frost gets in its deadly work. In a single winter in the northern latitudes such concrete is exposed to as much damage by frost as an ordinary building wall is subjected to in several years. It is therefore small wonder that relatively few years are necessary to accomplish the disintegration of the concrete surfaces under these accelerating conditions.

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* Of Metcalf & Eddy, Engineers, Statler Building, Boston.

An interesting and striking example of the effect of such circumstances as these may be seen in Fig. 1, which shows a portion of the effluent channel at the Fitchburg sewage treatment plant. This was built about 1910 under rigid specifications, by a good contractor, and with adequate inspection. It was good concrete and was undoubtedly of uniform character at the outset. The seriously disintegrated portions of the slope slabs are directly opposite the cascades which lead down the embankment from the secondary tanks near which the camera was located. These sections of the slab are constantly exposed to spray and spattering from the cascades, while the intervals between are comparatively free from wetting above the water surface in the channel. The result speaks for itself. Everywhere except opposite the cascades the concrete is in relatively good condition, considering its seventeen years of service.

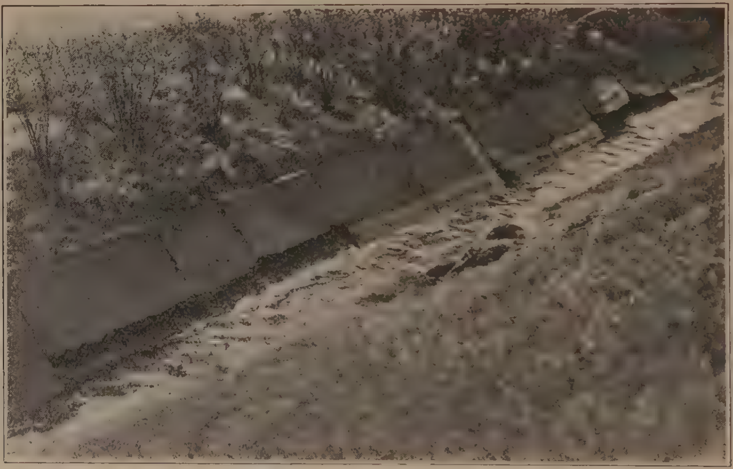

Fig. 1.— Portion of Effluent Channel at Fitchburg Sewage Treatment Plant

Concrete is not alone among building materials in its capacity for giving concern regarding its permanence and the continuity of its good appearance when used in locations exposed to the elements. Quite recently it was called to our attention that cracks had appeared in the cast stone used to face the lower part of a cylindrical brick masonry tower built from our designs to enclose and conceal a large steel standpipe at Syracuse, New York, as is indicated by Fig. 2. The original plan called for limestone, but cast stone of local manufacture was substituted as a measure of economy. These cracks are usually nearly opposite the joints in the courses above or below. There is no evidence that the cracks continue downward into the concrete foundation to indicate unequal settlement as the cause of the trouble. The exact cause has not yet been determined, but several suggest themselves. The blocks may have been insufficiently seasoned, permitting shrinkage after erection; if the mortar bed in which the blocks were laid was poorly applied so as to give unequal bearing, the blocks might fail as beams between the most thoroughly supported points under the heavy load of some 50 feet of superimposed brickwork; they may be subjected to severe temperature stresses, due to the fact that the interior is not heated; or the expansion and contraction on wetting and drying may have searched out weak spots in the blocks.

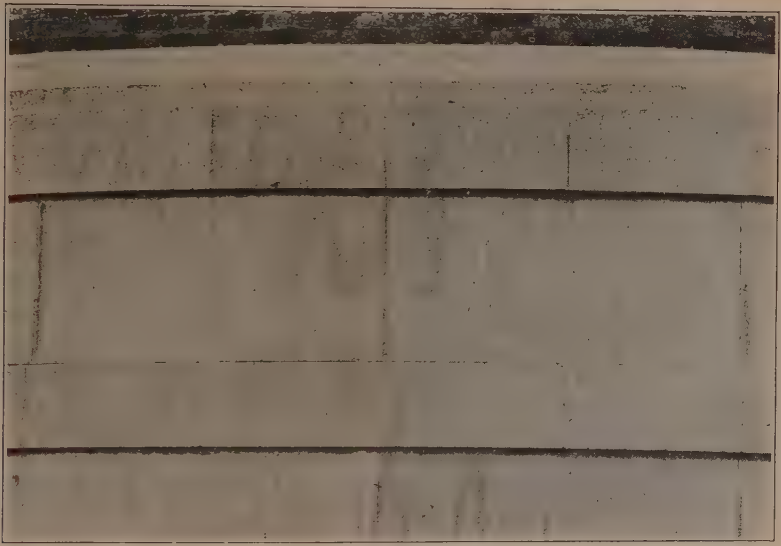

FIG. 2. — CRACKS IN CAST STONE AT BASE OF CYLINDRICAL BRICK TOWER

As a result of this experience with the Syracuse standpipe the speaker became interested in observing the weathering of the walls of other buildings and was surprised to discover numerous examples of cracking. While the causes have not been analyzed it may be of interest to mention a few instances to show what does happen and how a way is opened for the entrance of destructive forces. These may ultimately result in disfigurement so serious as to be quite as objectionable in high-grade buildings as is the more complete disintegration of concrete surfaces in industrial structures. Perhaps the materials may not be to blame, but the fact remains that cracking is occurring and must not be overlooked.

The terra cotta of the new Statler Building was found to be cracked. A crack was discovered in the limestone cornerstone of the new University Club, crossing the inscription on the Stuart Street face.

Fig. 3 shows serious cracking which has occurred in the limestone facing of the Paine Furniture Company building at the corner of Arlington and Stuart streets. Similar cracks may also be found on the opposite side of the show window, toward Stuart Street. The granite base course below the limestone is not cracked, but the crack finds its way to the joint which may be seen close to the corner. Unsightly cracking has taken place in the ornamental concrete base of the flagpole in the Public Gardens near Boylston Street.

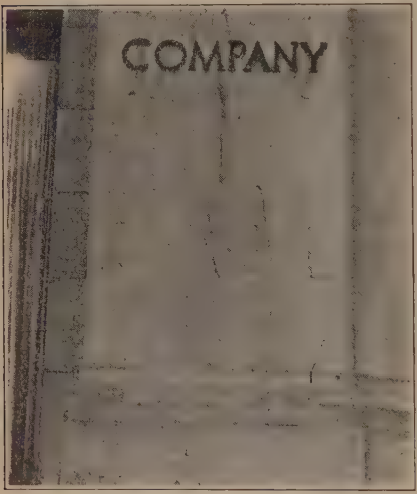

Fig. 3. — Cracks in Limestone Facing of Paine Furniture Company Building

No cracks were found in granite, but the observations do not pretend to be exhaustive. In any event, granite undoubtedly has greater structural strength than have the other materials mentioned, and distorting stresses from settlement, wind, temperature or other causes would seem to be more likely to be relieved in the joints than by cracking across the blocks. Brickwork also possesses a marked advantage in this respect, in that the joints are so close together as to encourage cracks to follow them and to be so dispersed as to be inconspicuous.

These examples are cited in order to point out the necessity for careful consideration, not only of the architectural effect of a material, but also of its suitability for withstanding any special circumstances which may affect the structure as a whole, such as extraordinary temperature ranges or unavoidable settlement in difficult material which the location or purpose of the building may impose. Permanence of good appearance will govern in some cases, while integrity of load-carrying ability will be the ruling factor in others.

H. S. CLEVERDON:* The discussion of masonry building materials is an extremely broad subject, which can be covered in certain parts, only, with the time allotted. All masonry building materials generally used in construction today have many merits or they would not be used. The same materials have their faults, some economical, others structural, and some possibly imaginary.

"The *faults* of building materials" seems to be the subject under discussion, and I feel that the failures or disfigurement of many of the building materials can be eliminated.

The greatest defect of all our present masonry work is cracking. The first and most prevalent cause of this is due to an imperfect structure. By an imperfect structure I mean one improperly designed or improperly constructed. All materials will rupture if they are overstressed. It is not alone due to improper design that cracks occur, but due to improper workmanship. It is seldom that masonry cracks as a whole, but when this condition occurs something is inaccurate in the design or the protection of the supporting members.

It is the small fractures of the individual units of masonry that are so detrimental to a structure's appearance. The rupturing of the various units is usually due to poor workmanship; that is, improper bedding of brick, stone, terra cotta or cast stone. Cracks in window sills offer the best example of this condition. If the sill is fully bedded in mortar the full length of the span, the weight of the piers on the end cause a compressing of the mortar at the ends during erection, and an upward pressure in the centre, causing the fracture. The rupture of units of masonry due to mechanics is familiar to all engaged in the engineering profession, so I will leave this phase of the subject and take up the more involved causes.

Within the last two or three years many of us have probably noticed the resetting of the masonry of two or three of Boston's structural steel frame buildings. This has been made necessary due to stone, brick or terra cotta becoming loose and fragments falling to the street. The fault has not been due to the failure of the masonry, as no unit of masonry has eroded, no mortar has washed out of the joints, and no frost has dislodged any unit. The cause has developed from the corrosion of the structural steel members.

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* Cleverdon, Varney & Pike, 46 Cornhill, Boston.

In fireproof structures the structural steel must be protected by fire-resisting masonry, and the general practice is to encase the steel solidly in masonry, brick, terra cotta or concrete. If the steel is not properly protected by a film of non-deteriorating paint before being encased, penetrating moisture will eventually corrode the steel. Corroded steel increases in volume, and being encased in masonry, the masonry breaks out in the direction of least resistance, usually on the exterior face of the building, and on the side of greatest corrosion, or the side where the moisture enters. Regardless of the material of the built-up masonry, — it may be the finest granite or marble, — this condition may occur unless the steel is thoroughly protected against corrosion.

The same condition occurs in monolithic or precast concrete buildings. There are many examples of concrete structures, badly defaced by the spalling of the concrete surfaces of spandrel beams and exterior piers or columns. The cause is the same as in the steel structures, but here there is a different condition. The reinforcing steel should have from 1½ to 3 inches protection of concrete from the exterior surface to the face of the steel. With this protective thickness of good concrete there is slight danger for the penetration of moisture from the elements. The difficulty exists in always obtaining this protection. If the column steel is forced within less than 1 inch of the surface in spite of spacers, or the spandrel steel is forced close to the form during pouring operations, the protective covering is not sufficient to prevent corrosion, and subsequent spalling takes place. I do not consider this an indictment against the use of reinforced concrete any more than I would consider corrosion of structural steel a justifiable indictment against the use of a steel frame.

The foregoing examples of deterioration or defacement of masonry cannot be charged to the masonry, but to their structural support. If modern masonry could be built with the meticulous care of the ancients, without the aid of other materials, troubles similar to the foregoing would not occur. I am sure that no one has seen any defects in the Ames Building, the first high building in Boston built in 1887. This building is semi-skeleton frame; that is, steel interior columns and floor beams with exterior bearing walls of granite on the street façades, and brick on the rear elevations. There has been no chance for structural members to disturb the masonry in this building.

Laying aside the defects due to structural and mechanical causes let us take up the defects due to the peculiarities of the various materials. Taking the natural stones in common use today there is little to say against them except the cost, and it is due to this fact that other materials are so generally used.

It may be worth mentioning here, however, that the commonly used sand stone, or brown stone of the middle nineteenth century, so commonly used in the residences built at that time, has shown a general tendency toward erosion or decay. In many cases this erosion was due to setting the stone perpendicularly to its natural bed. As brown stone is now seldom if ever used, we may eliminate this material from the subject of modern materials.

In general, face brick may be classed with stone for producing generally good results. Except for the occasional efflorescence common to certain clays from which brick are manufactured, brick have no serious defects when properly erected. Claims have been made that efflorescence can be prevented by various damp-proofing compounds and special preparations for mortar used in brick work. The damp-proofing, I believe, is but a deterrent of the appearance of efflorescence if brick are made of clay producing this defect. The damp-proofing in time loses its water-resisting qualities, and when this occurs the penetrating moisture brings the disfiguring salts to the surface, in solution, and they crystallize on the masonry surface.

The manufacturers of the special compounds for brick mortar claim that the mortar, being waterproofed, keeps each brick as a separate water-tight cell, preventing the salts from entering solution. I have not had personal experience with this method of prevention and would not pass judgment on its efficacy.

Leaving those building materials which do not cause any great concern, I will take up architectural terra cotta. This material, a product of clay, has seen great popularity in various localities. Boston and its immediate environs have not responded to this material with the same enthusiasm as New York and other cities. Nevertheless, enough architectural terra cotta has been used in this city to call this material one of our common masonry materials. I am going to discuss this material by citing two structures where architectural terra cotta has been generally used. The terra cotta in both of these buildings shows marked defects, but one has developed a deterioration far worse than the other. There is very slight difference in the age of these buildings, and both are equally exposed to the elements. One of the buildings is located on Boylston Street, and the other on Huntington Avenue. The building on Boylston Street is faced with a glazed terra cotta with considerable ornamentation. From a casual look at the building it is very doubtful if any one would see defects, but upon close scrutiny it is noted that practically every piece of terra cotta shows hair cracks in the glazed surface. The cracks are merely surface cracks, but they are there, and I feel they are a defacement. Whether they represent the beginning of a serious deterioration I would not dare to predict. The building on Huntington Avenue not only shows the same hair cracks but serious spalling, and through cracks. Here an actual defacement has occurred. This surface cracking is not only true of these two buildings, but I have seen it in terra cotta in Portland, Maine, Providence, Rhode Island, New York City and Philadelphia. What has caused this material to act in this manner?

My belief is that the range of temperature in this locality is too great for the material. The maximum difference in temperature in Boston during a year is between 90 and 100 degrees F.

Architectural terra cotta is made up of two materials, — the burned clay base and the porcelain-like finish. If the clay base has a coefficient of expansion of .0000031 per degree F., and the glazed finish has a coefficient of expansion of .000002, I feel the basic cause of the hair cracks is evident. Some sort of rupture must occur on the surface when two fused materials with different coefficients of expansion are exposed to the wide range of temperature differences in this locality.

However, why should some terra cotta fail to a striking extent while others only develop minute cracks? The answer to this is probably due to the burned clay base. I have seen some terra cotta the base of which appeared to have been burned to almost a vitrifaction, while other terra cotta has been but hard burned. I believe the nearer vitrifaction of the base the nearer equal are the coefficients of expansion of the glazing and the base, and the absorption of the basic material becomes less. If the basic terra cotta has a high absorption value moisture is sure to enter the basic material. When this occurs the moisture accumulates in pockets of the ornamentation, such as under cut moldings or crockets, where it is confined, and there can be but one result in freezing weather, and that is a spalling off of the surface. I am sure that freezing was the cause of the breaking off of the ornamentation of the decorative column caps of a building on which I had to make a report. Pieces had been breaking off for some time, and various recommendations had been made and tried but without success. The result is that a periodic inspection is now made and all loose and badly cracked pieces are removed.

In localities where there is not the great differences in temperature common to this locality, architectural terra cotta stands up well, and no better example of its endurance can be given than the ornamental terra cotta reliefs in southern Italy, where they have been in exposed positions for centuries without any indication of serious deterioration.

Cast stone, our latest material in the construction of buildings, has proven that it will endure and give good surfaces in imitation of many of our best building stones. It may be cast to meet the greatest diversifications the engineer or architect wishes. It can be cut so that the carvings are sharp and true, and in many ways it meets with general approval when it is inadvisable to use a natural stone if cost is a factor. About sixteen years ago a more or less monumental building was constructed of cast stone, and there was considerable criticism. A claim was made that the entire ashlar surface would have to be replaced in a few years. The building still stands with few imperfections, although from an architectural point of view the cast stone has not taken on the interesting weatherings of a limestone building. Cast stone, since the time of this building, has improved in its imitation of the natural stones, and it is improbable that the great majority of people not connected with building in its various phases realize the great quantities of cast stone now being used.

With cast stone being used generally, those of us who have had experience with this material have seen good and poor examples. Its greatest fault is the forming of map cracks or crazing on the exposed surfaces. The smooth-faced cast stone shows up this defect more than the tooled or planed surfaces. The prevention of this defect would increase the general value of the material, although I do not believe it is detrimental to its strength. I believe this defect is due principally to its manufacture. Take the concrete building block, which is so common in the cheap house foundations and one and two car garages. I have looked the blocks over carefully after they have been erected for a number of years, yet there is little or no crazing to be found. The reason for this is that these blocks are mixed with a minimum of water, the exposed faces are of the same mix as the mass of the block, and each block is a homogeneous mass of equal absorption value. These blocks certainly stand up well, in spite of a more or less makeshift manufacture. I am not lauding the use of these blocks, because from an architectural standpoint I feel they are hideous, but I do feel in the manufacture of these blocks the correct principle has been incorporated. I have seldom seen a specification for cast stone that did not read: "Cast stone shall match the sample in the architect's office." In order to meet these samples various materials, such as granite, marble and other stone screenings, with a large amount of fine particles, are used, and usually the surface part of the cast stone is but a small part of the mass of the unit. Here again, as in the architectural terra cotta, we have two different materials cast together and crazing appears. This crazing may be due to one or two causes, — the difference in temperature, or the action of the absorption of moisture acting on the colloidal condition of the cement and the fine particles making up the surface finish.

In pouring mass concrete the specification clause "all concrete shall be spaded between the concrete and the form " is now obsolete. We now specify the concrete shall be rammed in the form to remove air pockets and assure that the reinforcement is covered. The spading brought the fine materials of the concrete to the surface and map cracks under this procedure were very prevalent. Now that the face of poured concrete is homogeneous with the general mass, crazing is far less noticeable. I believe that if cast stone is made homogeneous throughout, and its density increased, the greatest detriment to this material will have been eliminated.

Taking our masonry materials now in general use there are few that will not stand up well during the life of a modern building, which is now claimed to be fifty years, and it will not be deterioration of the masonry that requires demolition, but obsolescence caused by ever-changing requirements.

It is only our monumental buildings and memorials that we expect to last for ages, and these are always built of our best natural products.

L. J. TOWNE * (presented by E. A. Dockstader †): It seemed to the writer that this subject might be of interest to those present this evening, because of the fact that a reinforced concrete chimney is an excellent example of what might be called accelerated weathering of concrete. The height, consequent exposure to wind, rain, and frost, the more or less continued vibration, and also the great difference in temperature between the inside and the outside surfaces, all contribute to a very severe test of the material of which the chimney is constructed. It might, therefore, be reasonable to suppose that any type of construction which would meet such conditions would surely meet the more usual conditions found in building construction, and that, *vice*

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versa, if the material were found not to stand up well under such conditions, an element of doubt would arise as to its behavior in other types of construction over longer periods of time.

The experience of Stone & Webster, Inc., with concrete chimneys goes back at least to 1907, at which time a large reinforced concrete chimney 17 feet in diameter by 268 feet high was constructed in Seattle. Since that time there have been constructed under our supervision a total of probably 50 or 60 reinforced concrete chimneys, the larger portion having been built since 1912. All of these chimneys are still in service, but a large percentage of those which were built prior to 1921 have suffered a considerable amount of surface cracking, together with some spalling and exposure of circumferential reinforcement. A stack constructed at Savannah, Georgia, in 1912 was found by inspection about a year ago to have a serious amount of spalling over its exterior surface and a disintegration over the inside surface due to the corrosive action of flue gases, extending in places to a depth of nearly 2 inches. This chimney has just been repaired on both inside and outside surfaces, by means of the cement gun, new reinforcement having been provided in the form of vertical and circumferential rods.

A stack which was constructed for us at Port Arthur, Texas, in 1917, has also reached a condition which necessitates the making of similar repairs to the exterior surface.

These examples will serve to indicate that the methods which have been in vogue in the past for reinforced concrete chimney construction cannot be said to result, in all cases, in permanent construction.

For many years the design of reinforced concrete chimneys was entirely in the hands of the chimney builder. While theoretical methods of analysis have been available for a long time, most chimneys were designed by "rule of thumb" methods which did not take into account any rational method for the determination of temperature steel, but which did result in considerably more steel in general than was necessary to meet the requirements of wind loads. About 1921 we observed that practically all chimneys which were being constructed for us suffered surface cracking, and we began to investigate the causes and to seek remedies for this condition. It became evident that temperature stresses were probably more important than stresses due to wind load, so in 1922, in connection with the construction of two chimneys at New Bedford, we undertook to take measurements of the temperature gradient through the shell of concrete chimneys, in co-operation with The Heine Chimney Company, so as to secure more data for bettering the proportioning of temperature steel. These data were published in a paper by Mr. E. A. Dockstader of our organization, presented before the American Concrete Institute in 1925. In the meantime we had arbitrarily been requiring a large increase in the amount of circumferential steel, so that in the more recently built chimneys we were using two or three times the amount previously considered sufficient. With the temperature measurements in hand, we developed methods of analysis of internal stress both for wind load and temperature stress, and it is our present practice either to design chimneys in the first instance according to the results of our analysis, or to check the manufacturer's design, thereby making such changes as are necessary to bring the design into conformity with our analysis.

It was also evident that the construction methods in use did not provide for positive positioning of the reinforcement, with the result that the reinforcement, particularly the circumferential mesh, was placed too close to the outside surface of the concrete. In such places the water readily penetrated the concrete, rusting the reinforcement, the expansive action of the rust spalling the concrete. It was evident that if construction methods could be developed which would accurately position the reinforcement, and if the concrete coverage over the reinforcement could be made more dense and impervious, and the outer surface of the concrete be treated to render it impermeable, this condition would be improved. The subject of construction methods was discussed with a number of chimney builders; and at least one of these contractors has now developed and is using a mechanical means of locating the reinforcing steel so that it is held positively in position during concreting operations. The importance of the accurate positioning of the reinforcement was impressed upon all of the chimney contractors, and marked improvement has been made in the care with which they are locating reinforcing steel.

We also continued the practice of testing concrete aggregates, making routine cylinder tests of concrete mixtures actually employed in the work, in an effort to improve the density of the concrete. Recently we have been experimenting with the use of admixtures to improve the workability and density of the concrete.

Due to the rapid removal of forms in the standard method of chimney construction, the concrete in the chimney shell is required to set under trying conditions of exposure to sun and wind, resulting inevitably in too rapid curing for proper strength and density. It was evident that improper curing conditions were perhaps the most serious defect in chimney construction, so last year several chimneys were constructed for us in which the surfaces of the chimney shell were kept continuously wet by streams of water sprayed from circular pipes around the inside and outside of the chimney shell, this piping being drawn up with the forms as the chimney progressed in height. The water applied at the top of the last completed section flows down over all previously completed sections and materially assists in proper curing of the concrete.

It was thought that anything which would make the surface skin of the chimney more impermeable would reduce the penetration of moisture and would naturally tend to reduce the possibility of rusting of the reinforcement and of frost action. In connection with two chimneys which were under construction in 1922, we tried on the one a fluosilicate wash, the other being finished in the usual manner. An inspection indicated that hardening of the surface was secured, and it was noticed that the surface of the chimney which had been treated with the fluosilicate wash remained clean for a much longer period of time than the adjacent chimney, indicating a denser surface. We have concluded, however, that a penetrating compound is preferable to a fluosilicate hardener, and we are now using on all chimneys a penetrating damp-proofing compound having a Stearate base. We believe that this material improves the resistance of the surface to weathering.

Another feature to which we have given attention is the surface finish of the concrete. For many years it was standard practice to apply to the outside of the completed chimney a wash of either lime and cement or neat cement. While this resulted in an excellent appearance of the chimneys when first completed, it was observed that the wash very soon weathered away, and, as might be expected, did not weather uniformly, leaving the chimney in a streaked or unsatisfactory appearance. The fact that the water curing of the concrete as it was poured improved the density and hardness of the surface made it still more difficult and impracticable to expect to obtain a satisfactory bond between the surface wash and the concrete. We have therefore abandoned the use of any surface wash and are concentrating our efforts towards producing poured concrete which will have a satisfactory finished appearance. The most difficult problem in connection with chimneys results from the fact that the texture of the concrete at the construction joints between successive lifts is inevitably different in character from that of the concrete poured directly against the steel forms. We are now experimenting with a method of rubbing the entire surface of each lift, immediately after the forms are removed, with a mixture of sand and cement rubbed over the surface of the concrete with a burlap bag. The sand and cement mixture acts as an abrasive, removing from the surface of the chimney, the oil which was applied to the forms, and we believe that this treatment will result in a more uniform appearance of the chimney as a whole. The rubbing is continued until all of the sand and cement mixture is removed except that which penetrates fine pinholes in the surface of the concrete. Since the rubbing is done while the concrete is green, the desired results can be obtained with a minimum of effort.

The net result of these efforts toward better design and construction has been a noticeably less number of cracks forming soon after the completion of the chimney. It is, of course, too soon to say how permanent these results will be, but we believe we are now in a position to construct concrete chimneys which will have a period of useful life definitely longer than did chimneys constructed five or ten years ago.

The methods employed are such as can be used with equal effectiveness wherever it is desired to produce concrete of high resistance to weathering. Summarizing our experience with reference to what is necessary for this purpose:

(1) Proper design, particularly with respect to providing adequate temperature reinforcement.

(2) The use of a dense impermeable concrete.

(3) Proper conditions for curing to insure ample water for the hydration of cement and the elimination of too rapid drying out of the surface.

(4) Proper positioning of the reinforcement to ensure its adequate coverage with concrete.

(5) The treatment of the surface of the concrete in some cases with a penetrating damp-proofing compound to increase its impermeability.

B. A. RICH:[*] For the purpose of this discussion I have examined some of the earlier concrete work in the vicinity of Boston.

Among the earliest concrete work in this vicinity are the shelters built by the Metropolitan Park Department at Revere Beach during the summer of 1897. The shelter near the bath house was examined quite carefully. The body of the walls is of mass concrete, without reinforcement. As I remember this work there was a coat of fine sand mortar placed on the surface. That surface today is in very good condition. There are very few hair cracks showing, but apparently no deterioration to amount to anything in thirty years in the body of the walls. However, the coping of these walls is made of concrete faced with a marble chip facing. This coping shows a number of small cracks; in fact, in some places it has become cracked badly. The cracking cannot be laid to the reinforcing, as there is none.

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The Lynn sea wall is frequently spoken of as showing deterioration, which it does below the high-water mark. Above the high-water mark it is now in very good shape, except parts of the coping, which has a marble facing. The marble chips in this work are considerably coarser than those in the Revere Beach work. Some of this deterioration is due to reinforcing bars which are near the surface; other deterioration cannot be laid to the reinforcing. The steps leading down to the beach show the greatest deterioration, due, no doubt, to the salt water. I found that the marble chips apparently had disintegrated. Evidently they have absorbed moisture from the salt water, and on expanding have disintegrated the concrete facing. Some of the marble chips were very brittle. The face of the main sea wall, which in the older part of the wall was a lean concrete, was rough picked. In general, it is in good shape. There is some spalling of the joints, due to expansion. The part built last had a facing of 1:2:4 concrete, and was rough picked. This part is in very good shape.

Another place visited was the work done by the same department in 1907, at Medford. This work contains a considerable amount of premolded block work. The premolded blocks were cast face down on the ground, and were faced with a mixture of 1:3 stone dust, apparently of trap rock. It was tooled or bush-hammered before being put in place. It shows practically no deterioration and is apparently as good as when it was placed, very few hair cracks showing. Other facing which was cast in place in the mass work had a fine gravel aggregate and was rough picked. This shows practically no deterioration.

Under the bridge at the Boston & Maine Railroad, where the face of an abutment was rubbed with carborundum block, the face still shows a very smooth surface and practically no hair cracks. An interesting thing is at the top of the base course of premolded blocks. At each joint in the base course cracks start and extend several inches into the face of the abutment. These cracks apparently were due to the temperature movement of the base being transferred into the body of the wall.

Frequent trouble has been experienced with the carborundum rubbing, and I think this is largely due to the fact that the wall has not been properly washed down after rubbing. If not properly washed down the mortar will eventually spall off. One wall finished with carborundum in 1908 showed no hair cracks or spalling. This wall had a mortar face of about 1: ½ or 1: 2, placed by using a sliding board to cast the facing integral with the body of the wall.

Another work visited was that of the Boston Elevated Station at Forest Hills. I don't know just what finish was used there, but it appears to have been washed down with acid after the forms were removed, as the aggregate is exposed deeper in some places than in others. This finish in general has stood up very well. There are cracks in the large columns, generally just below the railway level; also in the columns which are above the railway to support the roof, there are hair cracks about one-half the way up. I believe these are caused by vibration from the structure. On the inside of the large columns a crack shows directly in line with the steel columns. It is very common, with mass concrete encasing a steel member, to find a crack directly in front of the steel member.

Spalling of concrete due to reinforcing steel being near the surface has been mentioned, and, of course, is very common. Where the steel has been kept three inches in from the face no indication of corrosion of the steel has been discovered.

Now to consider the various building stones. A number of years ago there was a great deal of brown stone used in this section, and in many cases it has disintegrated. Some, however, has stood up well. One building examined recently, which I believe was built in 1880, has some finely carved work on the brown stone and a great deal of plain brown stone in the wall of the building. There is little or no spalling or deterioration. All the lines are sharp today. Apparently it was very carefully selected and laid.

Granite, which we think of as very permanent, may sometimes show considerable spalling of the surface of the stone by weathering, as is noticeable on the south side of King's Chapel. Approximately one-sixteenth of an inch has come off here in several places. On some of the older granite buildings, also, either fine-cut or bush-hammer work has been observed where the surface has disintegrated to depths of one-sixteenth to one-eighth of an inch. Generally, however, granite shows no deterioration.

Returning to the making of concrete: from what observations I have been able to make I believe concrete can be made practically permanent by the use on exposed surfaces of a fine insoluble aggregate and as dense a mixture as can be worked. The cast stone work which was done in Medford some twenty years ago apparently indicates that.

Trouble from salt water is a difficult problem. I have seen some concrete here in Boston which has stood salt water twenty or twenty-five years with very little deterioration; whereas close to it is another concrete which has deteriorated very badly. In general, the concrete which has stood up has been faced with a fairly rich mixture, with a fine trap rock or sand aggregate.

In regard to the use of marble and limestone as an aggregate, in a paper last year before the American Concrete Institute Mr. G. F. Loughlin of the United States Geological Survey called attention to the fact that limestone and similar aggregates, when used where constantly or nearly constantly in contact with water, do deteriorate quite rapidly.

In this vicinity we think salt water causes the greater part of our troubles, but last year I noticed, much to my surprise, considerable deterioration adjacent to the water line in fresh water. I don't know whether that is due to limestone aggregate or to frost action.

Apparently any building stone, natural or artificial, to stand our climate has to be composed of a non-absorbent, insoluble aggregate with some practically insoluble cementing material. Limestone and some of the marbles do show considerable weathering, but it is slow. Some old tombstones show that lettering frequently disappears in thirty or forty years, whereas slate, which is very dense, will retain clearcut marks for up to one hundred and fifty to two hundred years.

A. B. MacMillan * (presented by Mr. B. R. Switzer †): One of the interesting things about concrete is that there is always a problem to be solved. The problem now seems to be, "How can the surfaces of concrete buildings in this climate be made uniformly resistant to the effects of exposure to the elements?"

It is the common experience of all who come in contact with concrete structures to observe corners of columns or lintel beams cracked and spalled off, rusty bars streaking the surfaces with yellow stains, craze cracks with mesh-like ramifications, and at times the complete failure of small isolated pieces. While most instances of trouble seem to occur on the outside of the buildings, salt brine where used for pickling, and perhaps other materials, sometimes cause a like effect on the inside. Concrete chimneys frequently appear badly cracked, particularly near the top. Evidently there is still need of improvement if the slogan sometimes seen, "Concrete for Permanence," is to become universally true.

A discussion of individual instances of surface deterioration is not worth while; they are altogether too obtrusive for any one to have

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failed to see some glaring examples. As to a choice between the various kinds of cement and of aggregates, the elements seem to be equally impartial to all.

It may or may not be significant, but the writer has never seen any important sign of surface disintegration on the interior surfaces of concrete when kept dry, except that caused by wear or shrinkage; and in general, actually very little even around washstands in garages where water was flowing constantly across the surfaces to the drains.

Recently a discussion was printed in the "Proceedings of the American Society of Civil Engineers," Vol. 90, by John R. Baylis, entitled "Corrosion of Concrete," which, taken together with the discussions following it, seems to cover the ground of *cause* exhaustively, and perhaps to point the way to a possible cure or at least to a palliative.

This discussion has been so ably handled that it is with some diffidence that the writer ventures to join the debaters.

In the earlier days of the present concrete age the great expansion in the field of use of concrete and the available data relative to its behavior, was largely the result of the energy and faith of the contractors and builders. Gradually the physical and chemical research laboratories, the various engineering schools and others have sifted the mass of accumulated data and have disproven or proven and extended the knowledge relative to the material. As a result some of our ideas of porosity, permeability, void filling, mixing, plasticity, workability, slump, permanence, and of all the other catch phrases have been modified.

Today we are told, "Govern the water cement ratio and use any proportions of aggregates desired so long as the mixture remains workable," and the resulting concrete will be all right. Undoubtedly there is an element of truth in this statement, but like many generalizations it is not all of the truth. Many factors enter into the making of good concrete, beside cement and water.

Workability may mean to different individuals widely different degrees of viscosity or plasticity, and indeed, the requirements for actual workability will vary with the methods used for handling the concrete, the section to be poured, and the amount and spacing of the reinforcement. Nor can this be governed by slump tests. The amount of slump will vary with the personal equation of the tester, and with any given proportions of cement and aggregates will vary with the amount of water, the time of mixing, the size of the aggregates and the kind of aggregates.

As water performs at least two necessary functions, — (*a*) the hydration of the cement, and (*b*) the wetting of the surfaces of the aggregates, — it is obvious that with any given weights of cement and of aggregates the amount of water will vary not only with a change in the amount of cement, but in accordance with the surface area of the aggregates, which is a function of the size of the particles, and also with the absorption by them.

No study of water cement ratios, no care in proportioning or mixing, no investigation of slump can produce good concrete if the aggregates are in any way unfit. To make good concrete is an art requiring not only good materials, but that intelligence be used in proportioning and mixing them and in the disposal and protection of the mixed materials. With all of this preparation and care, if some of the constituents of the resulting compound are soluble in rain water, for instance, as indicated by Mr. Baylis, the results will not be satisfactory for use in exposures where such conditions exist. The writer is not a chemist so cannot prove or disprove the possibility of dissolving any of the compounds of the hydrated cement, but is perfectly willing to accept the statement that such solution may take place. There seems to be evidence enough in structures which are standing to indicate that with dense sound concrete such action is relatively slow in itself, and that the surface deterioration which is being considered is undoubtedly accelerated by other conditions.

In any study of probable causes the concrete should not be studied alone. Allied to it by bonds of close contact is the steel. At times the two materials are apparently content with each other's company; at others, they strive for divorce. It may well be that at times when there is no longer an entire singleness of purpose a rupture in the close fellowship may occur which will allow outside influences to gain entrance and break up the family group.

Mr. Lagaard, in a "Discussion on Study of Column Test Data," page 173, "Proceedings of the American Concrete Institute," states that "A combination of two materials, such as concrete and steel, one a material whose properties remain permanent under ordinary conditions throughout the life of a structure, and the other a material whose properties and dimensions are changing as time goes on, results in a strained relation between the two, which complicates their action under load."

To be specific: the coefficients of expansion and contraction for steel and concrete as a result of temperature are so closely alike that they may be considered identical. The wetting and drying of the surface of the building would, however, affect the concrete, causing it to expand and contract without having a similar effect on the steel. This effect in itself may be small, but assuming that a condition of internal stress exists in the concrete, even a small increment may be all that is required to produce an actual crack through which water can gain access to the steel. Should such access be gained, the expansion of the steel through the building up of oxides, assisted perhaps at times by the formation and expansion of ice crystals, would rapidly cause an enlargement of the opening.

That internal stress exists may be predicated upon the shrinkage of concrete during the first few months as it dries out and hardens. On page 489 of the "Engineering Record" for 1915, an article by F. R. McMillan, entitled "Shrinkage of Concrete and Conditions of Curing," gives a shrinkage of practically 1 inch for 100 feet in length of concrete. Taking the modulus of elasticity of concrete as 2,000,000, it may be demonstrated that if this contraction could be prevented by forcibly holding the ends of the specimen exactly 100 feet apart a stress of approximately 1,666 pounds per square inch would exist in the concrete. This, of course, is an impossible condition; nevertheless, the steel bars in the lintel beams, for instance, because of this bond with the concrete, do forcibly resist the contraction of the concrete, with the result that a condition of compression is imposed on the steel and a balancing condition of tension on the concrete. As the function of the steel in the loaded beam is usually to take tension, it is apparent that the tension already existing in the concrete adjacent to the steel must be still further augmented before a reversal of stress in the steel can take place and the steel enabled to act in the capacity for which it was designed.

Further data from various experiments on the plasticity and flow of concrete might be cited, but as they point in the same direction they will not affect the conclusion that internal stress does occur. It will perhaps be admitted that the reaction against this shrinkage of a bar located near the outer corner of the concrete member, for instance, will be unequally distributed in the mass of the concrete member, the effect being greater toward the outside edges than toward the interior of the member.

So far we have been discussing simply the effect in the long direction of the steel. The same shrinkage, however, occurs across the steel. It is upon this effect that we depend for bond when plain round rods are used. In this case, as the yield of the bar to the pressure of the concrete around it is slight, it must be assumed that unless there is some plasticity or flow of the concrete while shrinking and drying, which furnishes relief, the stress in the concrete in immediate contact with the steel, if based on a shrinkage of 1 inch in 100 feet, would be about 1,666 pounds per square inch. This stress would, of course, diminish rapidly in the fibers farther from the surface of the bar. Unless there is such an adjustment in the stresses, it is obvious that the concrete in close contact with the bar cannot take the strain without cracking.

It may therefore be assumed that there is an adjustment which relieves the concrete partially, at least, but that the relief is not complete, and that some stress still remains in the concrete. The amount of shrinkage, etc., will vary with the richness of the concrete, the amount of water used in the mix, the conditions of curing, etc., so no hard and fast statements can be made.

While these stresses alone may not be sufficient to cause cracks, and we assume they are not, as we seldom see such cracks in the interior of the building where conditions are fairly uniform, yet on the exterior surfaces they may be an ample cause when combined with the constant irregular volumetric changes in the concrete from moisture, heat, etc. Little imagination is necessary to enable one to anticipate that an occasional crack may be the eventual result, particularly if, as is too frequently the case, the steel during pouring is displaced so as to be quite close to the surface. Water during a rain storm tends naturally to run down and collect under the edges of the lintel beams or any other projection, and these points would usually remain damp the longest, so it is not unreasonable that they usually are the first to show signs of trouble.

In every case of deterioration examined by the writer, the corrosion of the steel indicated the presence of extensive cracks parallel to the steel bars, and might give ground for thought regarding the possibility of the wedging action of the deformed bars, provided the concrete slipped along them slightly in the shrinkage adjustment.

On the face of the evidence any condition of porosity, whether caused by poor proportioning, poor materials, solubility of cement compounds, or cracks from internal stress, is a potential cause of disintegration if the access of moisture to the reinforcement is permitted thereby. Sound dense concrete, deep embedment of the steel, good structural design, and, as an added precaution, the waterproofing of the concrete surface by means, perhaps, of a good china wood oil spar varnish protected with a zinc and titanium oxide paint, would seem to be the simple and necessary precautions to be taken for more permanent results.

Col. Sanford E. Thompson:* Some twenty-five years ago we received a sample of material. It was a light-colored, whitish material, rather soft, with some sand grains in it. You are all familiar nowadays with this material which rises to the surface of wet concrete, but then it was little known or commonly recognized; in fact, up to nearly 1900 most concrete was mixed of a dry consistency. We were much interested in this sample and other cases which came to our attention. At that time we had no laboratory, so Clifford Richardson, a chemical expert in cement, was employed to make an analysis of the material in comparison with Portland cement. He found the material to be nearly identical in composition with Portland cement, but it was amorphous, that is, noncrystalline. A study of French literature showed that the French name for this material was "laitance," and so I dubbed it laitance in our book "Concrete, Plain and Reinforced," then nearly ready for the first edition, and it goes generally by this name at the present time.

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The discussion tonight is on concrete surfacing, and this may seem to be unrelated to the internal action of wet concrete. There is, however, a clear and definite relation between the actions of concrete on its surface under improper conditions — the crazing or the chalky appearance, or the lack of hardness of skin — and the formation of laitance. The principles involved, and the causes of poor surfaces both vertical and horizontal, are the same as in the production of this laitance which rises to the surface of wet concrete.

As direct evidence of these relations I recall certain tests of sand-molded concrete blocks that I was called upon to make a good many years ago. Some of you, at least, are familiar with sand-molded blocks. To those of you who are not, I will say that these are made in the same way that cast iron is molded; that is, the wet sand is tamped around a mold of wood or plaster and the mold withdrawn, leaving the wet sand into which is pored the mixture of sand and cement. Excess water in the mortar is drawn out by the sand. This material — this sand-molded concrete — at that time gave a great deal of trouble with crazing and checking, and the reason was unknown.

We made an extended series of experiments and reached the same conclusions I have referred to in connection with laitance; that is, the water, for the mixture was very wet, was drawn from the mortar by the sand mold and brought with it to the surfaces of the blocks the fine particles of cement in a more or less amorphous state. This surface cracked and checked when exposed to the weather, especially to the sun and the rain. To cure this it was found best to make the mix of so dry a consistency as to just flow into the mold and to proportion for maximum density. I remember, for example, that we made tests of proportions and got as strong a mix with 1:7 as with 1:4. This was done by raising the size of the aggregates up to about three-eighths of an inch instead of using fine sand, and then pouring it as thick as it could be poured. To avoid crazing it was necessary to make the mix so stiff that it did not flow into the corners of the mold, and to get sharp details the surface was afterward tooled by machines.

The fundamental principle involved in the crazing, of course, is the same as in a mud puddle where the sun dries out the excess water and the fine particles shrink together forming the cracks.

At the present time the best quality of sand-molded concrete blocks are made in the way I have described. We occasionally find similar crazing on the surface of sidewalks, though not so much as in some other structures, because the surface of the sidewalk is made with coarse sand and of stiff consistency, and we have had so much experience in sidewalk laying that contractors know how to do it to make a good job.

A number of years ago, however, there was great trouble with the crazing of the surface of sidewalks in Chicago, because of the use of limestone screenings. There is nothing in the chemical composition of limestone screenings that is particularly detrimental, but they contain such a large proportion of fine dust resembling laitance in the cement that they produce a crazing surface. We are all familiar with the dusting of floor surfaces due to this very same thing. When the wearing surface is laid wet the laitance and the inert fine dust in the sand come to the surface and form a soft surface. As you all know, the secret of a good concrete floor is the use of coarse sand, or fine gravel with practically no fine particles, and the use of a very dry mix, as dry as can be placed.

In wall surfaces crazing is due to this same cause; that is, the amorphous cement particles incapable of hardening and produced by an excessively wet mix come to the surface, and on drying out, fine cracks are formed like those on a dried mud puddle.

All of these conditions, it is evident, involve the relative value of wet and dry concrete. Previous to about 1895 most concrete was made with a dry mixture. Then quite suddenly a very wet mix came about with the construction of concrete buildings where a more fluid consistency was necessary.

The theory of the wet mix looked so plausible that we started a series of tests with the expectation of proving how much stronger and better wet mixed concrete was than dry consistency concrete. This was some twenty-five years ago. We made up a lot of cubes and beams and columns, and the specimens all showed beautiful, smooth, apparently dense surfaces, and we expected to get good results. But, as you know now, the result was just the reverse of what was expected. The dry mixed concrete showed the greatest strength in every particular but one. And this exception proves the need of unbiased honesty in any research. At that time we had no laboratory, so we laid out a careful series of tests and had the cement and sand mortar briquets made up with the wet and dry mix in a laboratory here in Boston. I will not give the name of the man. He is not living at the present time. The laboratory report came in just as I expected; that is, that the wet briquets were reported as giving the greatest strength, and the dry the least strength. Because of this apparent discrepancy from the concrete cubes and beams and columns which we had tested, where the dry mix had shown the strongest, I did not dare to publish the results of the experiments. The undoubted cause of the apparent high strength of the wet briquets came to my attention some time after, during a talk with Mr. J. R. Worcester. He had had tests made by this same man and questioned the value of the results. So, to test his honesty, he sent him enough cement for 50 briquets and told him to make 100 briquets. The report came in with the strength shown of each one of *one hundred briquets*, notwithstanding the fact that there was only half enough cement to make the specimens. In other words, in our own case, the report evidently was made up from imagination, giving the figures not from actual test, but as he expected them to come. The tests were faked.

Some years later, in 1906, I presented the results of these wet *versus* dry concrete tests (I omitted the briquet fakes) before the American Society for Testing Materials. These tests and other series showed clearly the fact that the drier mixtures produced the greatest strength.

Another noticeable feature of the concrete specimens with which you are now familiar was that the dry mixed concrete was darker in color than the wet. This has a definite bearing on the matter of laitance of which I have spoken, for it is the laitance produced by the wet mix which causes the lightness of color of the wet-mixed concrete.

This also helps to explain the origin of the laitance. The question arises as to what this laitance — this soft material that rises to the surface of concrete — really is. Is it a soft material in the cement, or is it a change in the cement itself, — a change in the structure of the particles from crystalline to amorphous non-crystalline structure? From the appearance of the concrete it would appear that it is a change in the character of the cement; that is, that the crystals become noncrystalline in the presence of an excess of water, especially when excessively agitated. Wet concrete is lighter in color than the dry because a large proportion of the cement particles have been transformed by the action of the excess material and has this lighter material scattered through the mass.

Another principle which I have no time to discuss tonight is the greater freedom from laitance and the greater resistance in every way of a concrete proportioned to give the greatest density.

Summing up, then, — for I am bringing out these points to show some of the fundamental principles and causes of the difficulties that we meet in surfacing concrete structures, and the means of prevention, — we may say that in order to prevent surface deterioration there are certain principles that must be followed:

In the first place, we must avoid excess of fine material, either in the aggregates or through too large a proportion of cement.

In the second place, the concrete must be as dry as practical; that is, excess of water must be avoided.

In the third place, we must prevent — if we have to use even a moderately wet mix — the drawing of the cement to the surface, either by too much trowelling or porous forms or other means.

Fourth, we must proportion the materials so as to form a dense mixture with the greatest water-tightness and the greatest freedom from the tendency to shrink and check.

Edward H. Cameron:* — How will a building material stand up? The speakers have in general agreed that the answer depends on three things, — first, its make-up as to ingredients and care in making; second, range and frequency of temperature exposure; and third, exposure to moisture.

We in New England are fortunate in our granite supply. While this extremely durable building material is now less frequently used in commercial works, it still has an important place in churches and monumental structures, and is essential for bridge pier facing in our severe northern climate where concrete would rapidly deteriorate.

The firm represented by the speaker has recently completed several industrial structures and a power house in a manufacturing plant located in Alton, Illinois, on the east bank of the Mississippi, near St. Louis. This town is in the limestone region, and this is the local building stone, which is quarried from the bluffs along the river. Limestone is used for all construction purposes, including dwelling houses, retaining walls, quoins, window sills and copings for brick buildings, and track ballast. A large amount of the local concrete has this stone for an aggregate.

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* With Jackson & Moreland, Engineers, Park Square Building, Boston.

This limestone is very soft and quite soluble. From a distance a building constructed of this material presents an appearance similar to that of our granite, dressed to, say, a 1-inch projection. However, a "close-up" inspection fails to disclose the sharp points and corners to be noted in granite, as the stone surface weathers to a "washed-out" effect very similar to our cement blocks of the common garage variety known as "rock face." In some specimens it is possible to pick out loose fragments with the fingers. In some exposures a rainstorm will make a previously dull colored wall appear as though it had just received a coat of whitewash. The effect is sometimes striking in the small structures, from an æsthetic point of view, but is not pleasing from the viewpoint of durability. The local climate is much less severe than ours, and it is doubtful if this particular grade of limestone would be practical as a building material in New England.

As the new work under contemplation was to involve a considerable amount of concrete, careful inspection was made of local concrete in which this stone had been used as an aggregate. Much of this concrete was inferior. Exposed reinforcing was fairly common, and loose aggregate in a firm mortar matrix was frequently noted. The Boston men present were unanimous in laying the blame on the limestone aggregate, and accordingly river gravel was selected for all new concrete in spite of the greater initial expense due to a bridge toll of 50 cents a ton on all gravel used. The speaker's respect for New England's granite building stone and trap rock concrete aggregate was greatly enhanced by the above observations, and they are given here with the thought that they would be of interest to other Boston engineers.

Mr. Dockstader has discussed the effect of the combination of a severe temperature gradient together with exposure to weather in concrete chimneys. Engineers are indebted to the Committee of the American Concrete Institute, represented by Mr. Dockstader, for their investigations on the subject of temperature stresses in cases of this nature.

The speaker wishes to draw attention to the case of concrete walls exposed to the heat from boilers, open hearth furnaces, glass furnaces, etc. It is good practice to keep concrete as far away from such equipment as possible, and considerable ingenuity is necessary in properly protecting such concrete as has to be used in such places. If there is earth backfill behind the concrete the condition is aggravated, as the earth provides a very efficient insulation against the transmission of heat, and consequently very high temperatures in the concrete are obtained. Frequently this concrete occurs below ground-water level and cracks are serious.

In 1927 the speaker installed a glass furnace under conditions involving the above factors. The furnace consisted of a glass melting tank with regenerators on either side similar to those forming a part of an open hearth steel furnace. The furnace was installed in an old building under quite cramped conditions, and it was found impracticable to avoid instances in which the concrete work came as close as 6 inches to the outside of the regenerator pit and gas duct walls. Heat transmission computations, as well as practical considerations induced from examination of existing concrete work in close proximity to glass furnaces, pointed to the same conclusions, — first, that brick piers were preferable for the furnace loads; and second, that special arrangements should be made to protect the adjacent concrete work.

Accordingly, the spaces between the concrete and the firebrick walls and floors of the regenerator proper were designed to form wind circulating channels, using building tile and cast-iron tile through which wind was forced under a pressure of 3 inches (water column). In some places it was found possible to connect the system to the chimney lining space, thus taking advantage of the natural draft here. The wind system was connected to the cooling system of the glass tank proper which has to be in operation continuously during the life of the tank. About 5 per cent additional air was required for concrete protection.

Most of the discussion this evening has dealt with the slow deterioration of building materials under exposure to the elements. The above experience is cited as an example of precautions which must be taken against accelerated deterioration similar to the case of concrete chimneys mentioned by a previous speaker.

Irving B. Crosby:* Much has been said about concrete and comparatively little about the natural building stones, so possibly a few words about these from the geologist's point of view will be of interest, especially in regard to their comparison with concrete.

Mention has been made of granite as a building stone. If we consider its mode of origin we see that it is entirely different from concrete. It is an igneous rock, that is, one which has solidified from a molten mass, and is more like steel than concrete, except that it is composed of several minerals, crystals of quartz, feldspar, hornblende and mica, instead of one element. The first three minerals are very hard and make a strong, resistant rock. Although generally considered the most enduring of all rocks, granite has two weaknesses. In long-continued weathering the feldspar very slowly changes to kaolin or clay, thus breaking the bond between the other minerals and finally causing the rock to disintegrate. However, this change is so very slow in most climates that granite is good for a thousand years in buildings, which is much more than we can expect of concrete.

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The weathering of the feldspar crystals accounts for the fact that granite is not the most resistant of all rocks. If it were, Mount Washington, which is made of schist, would not stand 3,000 feet above the surrounding granite mountains. Schist is, however, unsuitable for building purposes, as it breaks easily in one direction and with a very ragged fracture in the other. The other weakness of granite is that it lacks resistance to fire. It cracks under great heat, due to the uneven expansion and the breaking of the quartz crystals which often contain small inclusions of liquid. This sometimes causes the granite to spall badly. Despite these two weaknesses it is a rock for which I have great respect, and it is probably the best of our building stones.

Sandstone is very much like concrete. It is, in fact, a natural concrete consisting of grains of sand cemented together. It all depends on the cement, whether the rock is good, bad or indifferent. Clay cement makes a soft sandstone; lime cement is soluble and does not produce a durable rock; iron cement is less soluble and the iron cemented sandstones are more enduring, but a siliceous cement in sufficient quantity produces a very hard, durable rock. Conglomerate or puddingstone is similar to sandstone, but the grains are larger, as it is composed of gravel instead of sand. It is a typical natural concrete, but is not much used as a building stone.

Limestone and marble have been mentioned frequently this evening. These are composed of lime which is soluble, and they therefore dissolve very slowly in water. If the water contains carbon dioxide the rate of solution is greatly increased. In cities there is much more carbon dioxide in the air, and the weathering of limestone and marble, chemically the same thing, is much more noticeable than in the country. The weathering of marble can be seen on old marble gravestones, and in some cases the lettering has become obscured. For ordinary buildings, which will probably be replaced in less than a century, limestone and marble are satisfactory building stones.

Slate is nothing more than baked, compressed mud. It is resistant to weathering and does not undergo chemical changes, but it is very soft and has a marked cleavage which renders it unfit for some purposes.

I think I have covered briefly the principal stones used in construction.

EDWARD A. VARNEY:* One point which perhaps deserves attention in connection with cracks in masonry walls is the question of avoiding heavy loads on any veneer work. It is a well-known fact that concrete shrinks when it sets, and mortar will also shrink, although perhaps to a lesser degree. A stone or cast stone veneer is usually in relatively large units with joints usually thin, while brickwork generally has a greater number of joints which are also relatively much thicker. Therefore the shrinkage would probably be much greater in the mortar in the backing than in the facing, and as a result there may be an unbalanced condition of loading, — more load coming on the veneer than was originally intended.

It would seem to me that the following precautions should be taken in order to avoid cracks:

1. The backing should be designed to carry the full load.
2. A course of veneer in each story should be laid later.
3. The joints in the veneer should be raked and pointed after the wall has set.

A somewhat similar condition exists in walls composed of face brick and common brick, or of face brick and hollow tile, either terra cotta or concrete. The face brick is usually harder and yields less. Since the materials have different resistances there is a tendency toward unbalanced load. I should say the precaution here is to make sure that the backing carries the real load.

Another feature which may lead to poor results is the tendency of some masons to "overlime" a mortar. Straight Portland cement mortars work "short," so that a common specification is to provide a 1:3 Portland cement mortar with the addition of 10 per cent of lime. This amount of lime may not suit the mason who wishes to use a mortar that works easily, and more lime may be added when "nobody is looking." If a mortar is oversanded, the tendency of the mason will be to add more lime to fatten the mix and get the mortar back to a workable condition again. As lime is quite soluble, "ribbon" effects or variations in color may result. Sometimes bulk lime is used for making the 10 per cent content in the mortar. This may be improperly slaked. If bulk lime is not properly slaked, bits of lime will "pop" and cause disintegration of the joints. There have been cases where bulk lime was slaked and used the same day, — a practice which would not be as easy to detect as with slaking lump lime for plaster work. I had called to my attention today the case of a wall which was leaking water badly, with the high wind and rain. This may have been caused by such mortar. I would say that the precautions here would be: —

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1. Specifying a 1:3 Portland cement mortar with the addition of 10 per cent of *hydrated* lime.

2. Careful inspection that the specifications are adhered to.

In addition to the point already brought out about the case of the corrosion of structural steel work not properly protected by concrete or a special paint, the expansion of the rust, and the consequent movement of the facing material attached to the steel, there is the matter of wall ties and anchors. I was asked the other day as to what I thought was the possible length of the effect of galvanizing on wall ties. I am not prepared to answer this, but I believe it is a point which deserves some further study.

If a combination of a very hard brick and a strong cement mortar is used, there is a tendency for the brick or the joints to crack from the effects of temperature. A hard brick will absorb little moisture, while a mortar joint may absorb a considerable amount, relatively. This may lead to disintegration at the joints, because the latter may freeze, causing expansion, with the subsequent breaking down of the surface bond. A precaution here may be obtained by the proper use of a waterproofing material behind the facing.

A feature which may not be as well known as some others is relative to the strength of terra cotta piers filled with concrete. The National Board of Fire Underwriters cite tests recently to show that such piers are not particularly strengthened by the filling with concrete, because of the different strengths and coefficients of expansion of the two materials. They also claim that concrete tile piers filled with concrete gain strength only slightly by the filling, and that it is not enough to warrant consideration. In view of this, there may have been cases where there has been too much carrying capacity assigned to such piers.

Another point which has been brought out already is the difference in the coefficients of expansion of the face material and the body of a unit. This is very important, such as in the glazing of architectural terra cotta, or the facing of cast stone. The usual tendency, which I think has been brought out, is to use too much fine material in the facing in the manufacture of cast stone products, with the incident result of "crazing."

With respect to framing, there may be one or two points worth mentioning. If a heavy beam or girder is not anchored to a wall, its expansion and contraction may cause end movement which may lead to minor defects in the masonry. If a pair of beams is planned to carry a wall jointly, the proportion of the load coming to each beam should be established, if possible, as otherwise the difference in deflections of the two beams may be harmful. Beams bent on a curve should be proportioned to resist the stress induced by the eccentricity of the wall load, and the end connections of the beams, if simply supported, should be investigated. There may be a tendency to put heavy beam reactions on relatively small bearing areas, leaving an unbalanced stress relation of the wall under the bearing plate compared with that each side of it. The old stone template idea had some merit in this respect.

I don't know whether it was the intention of the chairman to have anything included relative to stucco on masonry walls in this discussion, but a few points about this kind of work may not be amiss.

It seems to me that the so-called magnesite stuccos should be used guardedly for outside exposure. Such stuccos are usually a calcined magnesium oxide and magnesium chloride, which, when united with water, form a magnesium oxychloride (sometimes called Sorel cement). This product has a distinct cementitious value, but is soluble to a considerable degree in water, which breaks down the constituent elements. The material also contains lime in varying degrees, as an impurity, which is soluble. Magnesium chloride is a somewhat corrosive substance and may affect metal lath used in conjunction with it.

There used to be the practice of making the base coat of Portland cement stuccos a relatively lean mix, the scratch coat of a richer mix and the finish coat of a rich mix. This proved to be poor practice, and is along the same order of the different rates of expansion of the face material and the body of facing units.

Stucco should not be put on brickwork without wire lathing the surface first. There have also been a few isolated cases of stucco breaking away from terra cotta walls, although generally this is not as common. Doubtless the different rates of expansion have something to do with it.

Where wire lath is used, it should be attached with the proper furring nailing devices, so that the lath is out near the middle of the thickness of the stucco, to emulate reinforced concrete.

A factory sanded stucco will help to eliminate differences in shades of color and streaking.

An expanded metal lath is sometimes spoken of as "galvanized." If a sheet is reticulated, galvanized and then expanded, it seems to me that the galvanizing has been considerably weakened. Expanded metal galvanized after expansion, the manufacturers say, would be a very expensive process and is not done. However, it would seem that painted or japanned lath would lose some of its efficiency in bonding with the stucco. It seems to me that there is room for improvement here in the manufacture, or the alternate would be to use a wire fabric, galvanized.

Walter C. Voss:* Probably most of the information that we have on building materials of every kind has been developed in really usable form, and has been paid for by the firms who are supplying the material, and it has been their intent, all the way down the line, to produce a material that will do the best possible job. You all know that the Portland Cement Association has spent large sums of money for information along very similar lines, and all of the trade associations and material interests are coming frankly forward and admitting some of the troubles with their materials.

I want to call your attention to two things in connection with concrete, those in which I am most particularly interested at present. One is, "Where does density in concrete, or lack of density in concrete, lie?" and the other is, "What causes deterioration?" both considered from the fundamental point of view.

The Portland Cement Association, through the various bulletins which it has published, has stated that the various inert materials entering into concrete, — the fine and the coarse aggregates and also the water, — which must be considered an active material because it does its work with the cement, must be clean and sound, — structurally sound. If you are going to use any unsound material no one is to blame but yourself if the concrete is not up to standard. If you have structurally sound aggregates in a structure there will be practically no absorption. Unless you go to limestones or sandstones, which incidentally are not used around here, there cannot be any voids in the aggregates; and if the sand is siliceous material there cannot be any voids in the sand. The only possible place is in the combined mixtures. The voids are in the cement paste and are due to harsh mixtures. The voids are constant for workable mixes designed upon an economical basis.

Another interesting thing, which is true and quite surprising, about Portland cement concrete is the effect of pressure on density. Recent experiments have been extremely illuminating. An ordinary green concrete block was taken out of the molding machine and put in a machine and compressed so that it registered about 2,000 pounds per square inch compression. It was allowed to remain in the air about twenty-four hours and then sprayed for about twenty-eight days and the absorption was three-fourths of 1 per cent. That pressure, under the conditions for which that machine was constructed, forced the voids out of the cement matrix, caused dense mixing of the aggregates, and forced the water to the core of the grains of the cement. The minute water touches cement it starts to hydrate on the outside, and unless you have sufficient water and apply it, not in the mix but later, in order to continue that hydration to the core of the cement grain, you will not get the kind of concrete you are looking for. It is possible, also, to take concrete and increase its density by four or five points by proper curing, along the lines Mr. Towne has spoken of.

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* District Structural Engineer, Portland Cement Association.

I want to speak also about deterioration and to call your attention again to Mr. Towne's remarks in regard to chimneys. Laitance at the surface, inside of the concrete or at any other place you have it, is a source of trouble. When we use a soupy mix and spade the mix too close to the forms we begin to get laitance on the surface. It is possible to get a good looking job, particularly after it has been rubbed with carborundum, but the resistance is not there. No spading should be done nearer than within 4 inches in order to shove the concrete out to the form, and no opportunity should be given the wet mix to get to the face of the form.

The standard practice of the Portland Cement Association, laid down by the American Society for Testing Materials, should be followed. If you want to change those specifications it is perfectly all right, but don't change them unless you can tell us how we can meet them. If any man in the United States can tell the cement companies how they can make cement which will have the smallest amount of troublesome material, let him come forward, and the companies, no doubt, will start making it that way tomorrow. It isn't only the amorphous materials in the cement that may be causing trouble. There are millions of grains of troublesome materials for every cubic yard of crushed stone, gravel, etc., going into the concrete today. It is a dangerous factor, whether in the aggregate itself or in the surface coating, and leads one to the point developed by the American Concrete Institute Committee in connection with its work on crazing, which Mr. Bates of the Bureau of Standards heads, and that is, the importance of eliminating "fines." I don't care how you put the fines into the concrete. If you put an excess of fines into your concrete and then spade the mix to your form, so that those soluble amorphous or easily floated materials can get to the surface of the form, you are going to get crazing.

Granite was mentioned tonight. Personally I think granite is the finest building material we have, with no exception, not even steel. It is made of crystalline material and outside of decomposable mica, which occurs in veins, I think we can eliminate granite, as far as going to pieces is concerned. But granite is not well adapted to present methods of construction. It does not allow for live loads, occupancy, etc., where one must make allowances, and the reason our granite buildings do not go to pieces is because we have a lot of small units. On the Marshall Field warehouse, for instance, where the blocks are 10 by 4 feet thick and 2 feet high, approximately, some beautiful cracks have developed right in the middle of each lintel at the bottom. This is due to the type of thing Mr. Cleverdon talked about. The fault lies with us as far as concrete is concerned. We have got to get a concrete that will be as dense as possible, and it is contended that it does not make any difference; unless we apply pressure the density will be about the same. Prof. R. E. Davis has made tests in California on cylinders compressed by variously compressible springs with loads applied gradually and becoming greater and greater. These cylinders more nearly approached natural stone, and probably would be entirely devoid of crazing.

All the trouble lies directly at the door of density. Don't spade your concrete or play with it any more than you have to. The best example in New England that I know of is an old weather-beaten barn in the backwoods of Maine, where the forms were ½-inch thick boards to 2-inch plank. The ½-inch boards "bellied out," and while it spoiled the looks of the concrete from an architectural point of view, the structure is thirty-two years old and it isn't crazed and it isn't cracked. Put your concrete in place and let it alone.

Charles R. Main (by letter): * There are limitations in the use of most of the building materials. None of them are really permanent, but if used in the proper place they give good results. On the other hand, if the choice of materials is faulty, either a poor or an expensive job will result — very likely both.

Some ten to twelve years ago the town of Winchester had constructed a reinforced concrete standpipe. About six or seven years ago it had deteriorated so badly in great patches 2 to 3 feet in diameter that the reinforcing steel was exposed. At a considerable expense these holes were filled with concrete, the standpipe was waterproofed on the inside, and, so far as I know, is in good condition today. Whether or

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* With Chas. T. Main, Inc., 201 Devonshire Street, Boston.

not the effect of waterproofing will be substantially permanent remains to be seen.

In comparison with this job the town built, about thirty years ago, a steel standpipe, which, I understand, except for occasional painting, has had no repairs during this time, and is still in service.

I believe there are good examples of concrete standpipes in service today, but when not only the town of Winchester but other towns near by have had a similar experience with a concrete standpipe, it would appear that some material other than concrete is more suitable for this class of work. Generally speaking, steel standpipes can be built at a less initial cost, and can be maintained at a less yearly cost than concrete standpipes.

About three years ago our office built an intake tunnel for salt water for condensing purposes. The invert of this tunnel is at grade −9, and the tunnel, being 6 feet in diameter, is always filled with water. The tunnel was made of precast concrete pipe of 6-foot lengths, of a very dense mix, 1:1½:3, and the inside surface was waterproofed. After the pipe was laid, the joints were also waterproofed. The walls of the intake chamber and of the manholes were faced with granite and brick, respectively, to protect the concrete surfaces from spalling on account of alternate freezing and thawing at the water line.

Concrete surfaces of buildings are in most cases merely rubbed down with a cement grout to produce a good finish. Sometimes these surfaces are treated chemically with a damp-proofing compound, the effect of which would be to retard deterioration but not permanently prevent it.

One of the most permanent treatments of exterior walls of buildings is obtained by the use of water or sand struck brick with granite trim. A great many mill buildings have been built of these materials and are still in good condition after many years of service. On account of the present high cost of granite, artificial stone has, in recent years, come into common use. None of us can predict how long this artificial stone will last, but we do know in many cases it has not stood up as well as the natural stones. It is difficult to handle without being chipped, but has the advantage over granite and other stones that it can be patched, and, in addition, its initial cost is considerably less. Perhaps it will last as long as the building is serviceable.

One of the most recent examples of a good cast stone job is the new State Street Trust Building, which appears to be weathering without appreciable deterioration. I understand that the surface of this building was not treated with any damp-proofing compound.

OF GENERAL INTEREST

EFFLORESCENCE OF BRICK WALLS

General Conclusions Reached in Study Being Made of this Subject

By Edward H. Cameron *

The writer has recently noted a reference to the subject of efflorescence of brick walls in the Journal of the American Ceramic Society for January, 1928. This gives a "Progress Report on the Efflorescence and Scumming of Mortar Materials," by Mr. Hewitt Wilson, and covers a co-operative study by the Pacific Northwest Brick and Tile Association, and the University of Washington. As this subject is of general interest to architects and engineers engaged in brick building construction, the "General Conclusions and Summary" of this report are given below.

(1) Since water is the only carrier of soluble salts, the best preventive of mortar or wall efflorescence is the absence of water. It is well to avoid soaking porous brick any more than necessary, and to permit the wall to dry out thoroughly before it is given its final cleaning. All brick work should be protected from leaking drains, cappings, sills, etc. While a heavy rain driven by the wind will penetrate, a light rain will have very little effect in producing scum. Sufficient water in contact with all our common mortar materials for a sufficient length of time will cause scum.

(2) Portland cement and its products, concrete, artificial stone block, and cement brick, carry a large quantity of easily removed salts such as calcium hydroxide, calcium sulphate, and others which, up to the present time, have not been retained by the so-called waterproofing compounds. These Portland cement products have large continuous pores through which dissolved salts and even calcium hydroxide in suspension can pass out to adjoining surfaces and produce discolorations.

(3) Scum was produced with all of the mortars used in the present panel tests. Sufficient water and time for soaking was all that was necessary. The first and worst scum in the beginning was rich cement mortar. Salt water replacing fresh water in the mortar also gave a quick scum which probably in a long period of time will gradually be removed. It, however, produced a very weak mortar and should be avoided. The scum from lime mortars was only produced by large quantities of water in long contact with the interior of the wall. The type of scum produced from lime alone has not been seen by the writer on walls in use save those in contact with fresh cast stone, and therefore it is not believed to be a serious factor for ordinary brick work. However, it is better to use lime putty which contains no lumps of overburned or other slowly slaking portions which carbonate slowly and offer a continual

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* Of Jackson & Moreland, Engineers, Park Square Building, Boston.

supply of calcium hydroxide. Hydrated lime, because it has been screened, appears to offer a lime mortar which is freer from this defect than the common water-slaked lime.

(4) Barium carbonate has proved effective in preventing the temporary efflorescence of calcium or magnesium sulphates. Barium carbonate will not prevent the scum from lime hydroxide suspensions from Portland cement, cast stone, or other cement products, or from uncarbonated lumps of lime in lime mortars. It will not prevent the scum from salt water. While the more soluble barium salts act more rapidly, yet rapid action may not be necessary. Barium chloride, reacting with calcium sulphate, produces the soluble calcium chloride which will produce a scum itself. Barium hydroxide may be preferable because it produces calcium hydroxide or a form of lime putty. The extra cost of barium hydroxide has not yet been justified.

(5) Barium salts only act on one type of efflorescing salts. Other compounds may be found to take care of the remainder. A universal solution of the problem may lie in the development of a waterproofing compound which will not only fill the voids or surface voids of the mortar, but also of the brick and cement products.

Why Specifications?

By Edward Grossman *

Much criticism has been directed by contractors at some of the specifications which are issued, and upon which the contractor is expected to base a bid or construct a structure. The contractor finds that it is a pleasure to work according to specifications issued by some engineers and architects, while it is quite the reverse when he has to contend with some of the other kinds of specifications. It seems that to some engineers and architects the specification is of little moment, to be issued only because it is the fashion to make up a set of specifications with a set of plans. To them "the plan's the thing," and the specifications mean little or nothing. There are, however, both meaning and status to a specification.

First of all, the specifications are important as a construction document. The purpose of a specification is to make clear, to an extent impossible on plans, the materials and methods to be used in construction of the work under consideration. It is obviously impossible and undesirable to letter up a drawing with copious notes and instructions; there would soon be no room for the drawings. Obviously these instructions and notes must be gathered and put in a separate document containing explanations and nothing else. Thus, obviously, the function of specifications is explanation.

To explain is to make clear. Therefore there must not be any ambiguous clauses in the specifications. Ambiguous clauses, because of their uncertain meanings, are weak; consequently an ambiguous specification is weak, and uncertainty in instructions makes a poor job.

The specification has also a status as a legal document. It is part of the contract between the owner and the contractor. It is usual in every construction contract to tie in the plans and the specifications with the contract itself. Then the specifications, far from being a mere appendage of the plans, become a vital part of the contract, for they exhibit the intent and purpose of the engineer or architect in designing the structure. There is no way of avoiding the issue. In case of dispute, the question arises: What did the designer of the structure mean? And the specifications are expected to give the answer.

Contracts are quite an important item in law, and certain principles and forms must be followed in order that the contract may be valid. We, of course, are interested at present in the validity of a contract only as it is affected by the clearness of language used in the specifications, which are a part of the construction contract.

---

* Estimator, with Benjamin Steinberg, 6 Beacon Street, Boston.

Clearness of language in a contractual sense means the exact definition of the rights and duties of the contracting parties. Just as the sum of money involved in the contract must be clearly denoted, just so clearly must be denoted the description of the work that the contractor is to do. The usual place to define the contractor's work and status is in the specifications; therefore the specifications must be written in clear language. One requirement of clearness is so extremely elementary that to state it takes one back to grammar school days. "Every sentence must have a subject and a predicate." Sixth-grade stuff, isn't it? Yet it is surprising how very many specification writers forget his rule.

How clear is this sentence? "All as specified." Of course, to specification writers it means something, and so it does to contractors versed in the jargon of specifications; but how about a third party who may have to act as an arbitrator or a judge with the case before him? Can a group of words such as the above — they do not form a sentence — be enforced by their author? The question of clearness brings us to the methods of writing specifications.

There are several methods of writing specifications. One method is to copy clauses or entire sections from existing specifications or from copy books, one or two of which are on the market. Another method is to take an existing specification and merely change the title-page. Still another method is to compose a new specification for each job. The latter method, while most desirable, is, of course, most expensive. And expense nowadays cannot be hanged.

There are certain clauses which may be used in most specifications, and if the specification writer makes up his own copy book and uses care in copying he probably would not come to grief. Great care must be taken to see that incongruities do not creep in, for it is indiscriminate copying which leads to mistakes.

A very common mistake is to issue a specification too severe for the job it covers. It is obviously foolish to specify the testing of each carload of cement on a job that would use about one hundred barrels. Or if ten small I-beams are required to support a light roof, why demand shop inspection facilities?

One recent specification distinctly states that the cement used is to be American Portland cement, —— brand, and is to come on the job in original, unbroken packages. The last sentence in the paragraph reads: "If foreign cement is used, it must be tested and report thereof submitted to the Architects." Imagine the temptation, with foreign cement as low as it is today!

Another specification has the following to offer: "Where no weights are marked on the structural plans opposite the sizes of the sections required, the heaviest section of that size is to be used." Thus if I see a column marked "14″ BH" I am to figure on using the heaviest section, 288.5 pounds to the foot, even if only the lightest section, 84 pounds to the foot, is required.

Sometimes clauses entirely foreign to the work under consideration are found in a specification. This usually happens when a specification is written by merely changing its title-page.

Where specifications are not checked with the plans, omissions occur. Of course, it is the duty of the contractors to check the plans and the specifications and supply omissions, yet they do not do it, and arguments result.

This brings us to a summation of the qualities a set of specifications should possess.

A specification should be terse. The average engineer or architect is not an essayist or a lawyer, and he should not try to imitate the rhetorical pyrotechnics of the one, nor the legal phraseology of the other, or the main point will be lost in a meaningless flood of words.

A specification should be clear. It should say only what is relevant and intended. References to standard specifications, such as those of the American Society for Testing Materials, should be unmistakable. Work to be done by one subcontractor should be kept together. Different classes of work should be segregated in sections under section headings. Enough definitions should be given in the section of "General Conditions" so that there would be no question as to terms used.

A specification should be complete. It should be checked with the plans, so that there will be no need of specifying that the contractor should supply omissions not called for on the plans or in the specifications. Contractors soon get to know these incomplete specifications, and they allow for omissions, in which case the engineer or architect is, of course, surprised to find his bids running high.

Standard forms, such as the "General Conditions" of the American Institute of Architects, should be adopted and used as widely as possible. Professional societies should compose and adopt such standard forms, and encourage their general use. Not only will the issuers of specifications save time and money by having these printed forms, but what is more important, the specifications issued will be superior, and there will be less chances taken in figuring jobs.

Opportunity to Study Abroad

Another John R. Freeman Travelling Scholarship will be made available in the Society this summer. This scholarship provides for one year's study and work in the European Hydraulic Laboratories. The stipend is $1,800. The award will be made early in June in order that the recipient may sail not later than July 1, 1928. *Complete details of this scholarship will be given in the April issue of the Journal.* The Freeman Fund Committee believes that this is an excellent opportunity for one of the younger engineers to learn what has been done abroad in the application of laboratory research to hydraulic problems.

At the present time Kenneth C. Reynolds, an instructor in the Civil Engineering Department, Massachusetts Institute of Technology, is in Germany under the auspices of the Freeman Fund of the Society. There are also six other engineers engaged in similar studies in Germany, three sent by the American Society of Civil Engineers, two by the American Society of Mechanical Engineers, and one on a fellowship established by Technology.

This travelling scholarship offers an excellent opportunity to study hydraulic problems of all types — river and canal flow, harbors, sea coast protection, turbine development, etc. All of these are important subjects and are coming to the front more and more in this country.

In awarding this scholarship preference will be given to those who intend to teach in an engineering college.

Complete information as to form of application, etc., will appear in the April Journal and by special announcement to all members of the Society. In the meantime if more information is desired, apply to the Secretary of the Society.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS

Boston Society of Civil Engineers

February 15, 1928. — A regular meeting of the Boston Society of Civil Engineers was held this evening in Lorimer Hall, Tremont Temple, and was called to order by the President, Frank A. Marston, at 7.15 P.M.

This was a joint meeting of the Boston Society of Civil Engineers; Northeastern Section, American Society of Civil Engineers; M. I. T. Student Chapter, American Society of Civil Engineers; Harvard Engineering Society; Tufts Civil Engineering Society; and the Northeastern University Section, Boston Society of Civil Engineers.

The meeting was preceded by a buffet supper and smoker in Chipman Hall, at which music was furnished through the courtesy of the Northeastern University 30-piece band. About 400 members and guests of these societies attended the meeting.

The reading of the minutes of the previous meeting of the Society (January 25, 1928) was omitted.

The President reported that the Board of Government, at its meeting today, had elected eighty-three new members to the Society. A list of these members follows:

Members: Charles B. Abbot, Otis D. Allen, William L. Biggart, Morris G. Blumberg, Ralph D. Booth, Richard P. Boyer, James F. Brittain, Frank M. Carhart, Charles L. Coburn, George W. Coffin, Wilbur S. Colby, Arthur A. Corcoran, John C. Damen, Henry I. Fitz, Dean B. Fraser, Albert Genaske, Lawrence M. Gentleman, Ernest H. Gillette, William M. Gooden, Abram C. Hammatt, Stanley A. Higgins, John A. Lunsford, Frederick W. Meyer, Donald E. Moore, Verne O. Nelson, Clarence E. Pethybridge, Walter J. Reed, Russell J. Rice, Trygve Rusletvedt, Samuel W. Sweeney, Israel Swirsky, Walter C. Voss, Francis B. Wilkins, Thomas Worcester.

Juniors: Howard F. Allen, John B. Belknap, John D. Bradford, Samuel W. Brooks, Albert W. Bury, Joseph P. Carney, Russell C. Chase, Arthur E. Colvin, Eugene B. Condon, Frank H. Cosgrove, William C. Custer, Almon C. Davis, Malcolm E. Deacon, Raymond A. Freeman, Edwin B. Gates, Marcello J. Guarino, Carlton W. Hathaway, Frank Heaney, Roger R. Hilton, Theodore W. Homkowycz, Lionel La Belle, Joseph A. La Fauce, Harry T. Leonard, William H. McGinness, Otis W. McIntosh, John J. Meehan, Frank C. Meyers, William C. Morrill, James S. Mozzicato, William J. Nilan, Bernard A. O'Shea, George N. Perry, B. Arthur Potter, Robert J. Prowse, Henry A. Radzikowski, Joseph B. Rigo, Earl Robinson, Israel Shanbaum, Edwin W. Southworth, Jr., Woodworth P. Stoddard, Kenneth D. Sylvester, Victor A. Thurston, Virgil A. Thurston, John G. Tighe, Kenneth S. Ulm, Sebestino Volpe, Charles A. White, Forrest S. White, Thomas C. Winebaum.

The President called attention to the excellent work which had been done by the Committee on Membership and Publicity, and stated that they were largely responsible for securing so many new members.

The President then introduced John H. Gregory, Consulting Engineer, Professor of Civil and Sanitary Engineering at Johns Hopkins University, Baltimore, Maryland, who gave an illustrated talk on "The O'Shaughnessy Dam and Reservoir." Following the presentation of the paper, Professor Gregory answered a number of questions concerning it. (This paper was originally presented before the American Society of Civil Engineers at Columbus, Ohio, on October 12, 1927, and has been printed in the American Society of Civil Engineers Proceedings of February, 1928.)

At the conclusion of the talk a rising vote of thanks was accorded to Professor

Gregory for his courtesy in coming to Boston to give this address.

Meeting adjourned at 8.50 o'clock.

J. B. Babcock, *Secretary.*

Designers Section

February 8, 1928. — The meeting was called to order at 6.20 p.m. by the chairman. The minutes of the previous meeting were not read, having been published in the Journal. It was announced that the election of officers for the coming year would take place at the March meeting, and the chairman requested a motion, which was duly made and seconded, that a nominating committee be appointed. Following precedent the chairman appointed to serve on this committee the three past chairmen of the Section, Messrs. Edward H. Cameron, J. Stuart Crandall, and Waldo F. Pike.

The speaker of the evening, Mr. Abel F. Stevens, Landscape Engineer, spoke on "The Practical Use of Explosives." Mr. Stevens' experiences were unusually interesting, and their description was accompanied by three reels of motion pictures illustrating the use and manufacture of explosives. Many of the thirty-seven members and guests present asked questions which were readily answered by Mr. Stevens.

The meeting adjourned at 8.30 p.m.

Norman P. Randlett, *Clerk.*

Highway Section

January 25, 1928. — A special meeting of the Highway Section was held in the Affiliation rooms January 25, 1928.

The minutes of the previous meeting were read and accepted.

The speakers of the evening were Mr. J. A. Johnston, District Engineer, and Mr. R. W. Coburn, Construction Engineer, both of Massachusetts Department of Public Works.

The topic was "Relative Merits of Gravel and Stone Fill for Highway Foundations."

A very interesting discussion followed.

About fifty members and guests were present.

H. F. MacWilliams, *Clerk.*

APPLICATIONS FOR MEMBERSHIP

[March 20, 1928]

The By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of fifteen (15) days from the date given.

For Admission

Davidson, John Clark, Dedham, Mass. (Age 37, b. South Boston, Mass.) Graduated from Mechanic Arts High School, 1908. From 1908 to October, 1917, worked for Aspinwall & Lincoln. Resigned as chief of party to enlist in the 6th United States Engineers. Returned from France July, 1919, and went to work for the city engineer of Medford. From 1919 to October, 1925, was engaged in municipal engineering with the city of Medford and resigned to accept a position with the county engineer at Dedham, where he is to date. Refers to *E. P. Adams, C. B. Humphrey, E. H. Lincoln, H. L. White, Erastus Worthington.*

Fitzgerald, Michael J., Worcester, Mass. (Age 37, b. Worcester, Mass.) Educated in the public schools of Worcester and Business College; also spent four years studying law in Northeastern University, Worcester. Served in an advisory capacity as a member of City Council, Street Committee, Worcester, five years; employed eleven years as salesman selling road oils and asphalt and advising city and town engineers; at present in the same capacity for the Texas Company, Boston. Refers to *W. G. Classon, F. W. Guerin, S. H. Pitcher, R. A. Vesper.*

HASTINGS, RAYMOND GEORGE, Belmont, Mass. (Age 30, b. Weston, Mass.) Graduate of Tufts College, Engineering School, in 1920, with B.S. in mechanical engineering. During the summer months of 1911 to 1920 was employed by the city of Newton as rodman and transitman; 1920–21, student engineer employed by Worthington Pump and Machinery Corporation, Blake & Knowles Works; one year of supervised training in all departments of iron and brass foundries, pattern and machine shops, office, etc.; 1921–27, assistant construction engineer, Blake & Knowles Works; 1927 to date, with Jackson & Moreland. Refers to *W. D. Henderson, G. G. Howie, W. P. Morse, H. B. Perry, E. H. Rogers.*

LATIMER, LLOYD CURTIS, Somerville, Mass. (Age 32, b. Somerville, Mass.) Attended Boston Y. M. C. A. Evening Polytechnic; civil engineering, Franklin Union, a year and a half; Northeastern University (evenings), one year; and at present taking structural engineering at Franklin Union. Experience: five years as rodman, city engineer's office, Somerville; two years in United States Naval Reserves; four years as transitman, city of Waltham; one and one-half years with Barnes & Beal and G. F. Clements; one year with Boston Elevated as transitman; three years to date, as transitman, and now assistant engineer with the city of Medford. Refers to *Robinson Abbott, W. B. Birkmaier, J. G. Brackett, E. W. Danforth, O. J. Whitney.*

LINEHAN, MICHAEL J., Charlestown, Mass. (Age 25, b. Boston, Mass.) Attended Franklin Union for the last four years where he is now completing a course in civil engineering. Worked in the drafting room, Navy Yard, Boston, for five years. Refers to *Robinson Abbott, S. L. Connor, E. A. Graustein, L. M. Hersum.*

NEWCOMB, CHARLES WINTHROP, Medford, Mass. (Age 27, b. Hyde Park, Mass.) Graduated from Hyde Park High School in 1918 and completed Lowell Institute building course in 1922. Employed by Fay, Spofford & Thorndike from January to September, 1920; September, 1920, to January, 1921, with Boylston Realty Corporation; January, 1921, to January, 1922, with Constructing Quartermaster of Q. M. C., at Boston, under civil service; March, 1922, to date with Putnam & Cox in charge of designing construction. Refers to *C. R. Berry, Erwin Harsch, F. E. Leland, W. F. Pike.*

PETERS, ALEXANDER C., Medford, Mass. (Age 38, b. Medford, Mass.) Spent one year at Tufts College; tutored in structures one year; three and one-half years railroad maintenance and construction as rodman to chief of party, Boston & Maine Railroad; two and one-half years with Stone & Webster, Inc., job, field and assistant engineer, steam power plant, hydroelectric, transmission lines, rock tunnel; four years, valuations, appraisals, investigations, public utilities, etc., for C. D. Parker & Co.; two years in United States Army; eight years in business as A. C. Peters, surveying, construction, etc. Refers to *C. B. Humphrey, C. R. Main, A. L. Shaw, O. J. Whitney.*

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DEATHS

Austin B. Fletcher . . .	March 8, 1928
Bertrand T. Wheeler . .	March 20, 1928

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